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The Feasibility of Utilizing Cluster Sampling in the Navy: A Demographic Comparison of Cluster and Stratified Random Samples

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13. ABSTRACT (Maximum 200 words)

Traditional mail surveys sent to randomly selected members have been the predominant data collection mechanism to assess the attitudes and opinions of U.S. Navy personnel. Over the past ten years, response rates on large-scale Navy surveys have steadily declined. For example, the Navy Equal Opportunity/Sexual Harassment (NEOSH) Survey, which is mailed biennially to a Navy-wide sample, dropped from 60 percent in 1989 to 30 percent in 1999. On-site survey administration at selected Navy fleet concentration areas has been suggested as a possible solution; however, this sort of convenience sampling is not scientific and cannot be generalized to the Navy's population. If a methodology could be utilized that linked targeted command survey administration with representative, scientific sampling, many of the shortfalls in current Navy survey administration could be addressed. The purpose of this study was to determine the feasibility of utilizing cluster sampling to develop a statistically representative, scientifically valid sample at randomly selected Navy commands. This study statistically compared the demographics of a cluster sample to a stratified random sample.

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Foreword

Navy leadership often gathers information from its personnel to aid in decision-making and to direct policy. A number of methods have been used to collect this information, including interviews, focus groups, mail- and more recently, online-administered surveys. In an effort to improve the quality of responses from Navy personnel on these studies and to contribute to the scientific literature, methodological studies are conducted to assess the efficacy of different data gathering approaches. This report presents the results of one such study designed to determine the feasibility of utilizing cluster sampling to develop representative samples at randomly selected Navy commands.

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Summary

Response rates on Navy surveys have declined dramatically in the past decade. If this trend continues, the validity of survey results may be threatened, causing Navy leadership to lose confidence in the results. Alternative data collection techniques need to be explored. Data collection at Fleet concentration areas has been suggested as a possible solution. However, this sort of convenience sampling is not scientific and results cannot be generalized to the Navy's population. This study seeks to determine whether, despite the Navy's transient, geographically dispersed environment, cluster sampling can be used to develop statistically representative, scientifically valid samples at randomly selected Navy installations.

Objective

The goal of this study is to determine whether cluster sampling can be used to develop representative samples of Navy personnel for data collection using randomly selected Navy installations. To accomplish this, the demographics of a cluster sample were compared to the demographics of a stratified random sample of Navy personnel.

Approach

A two-stage cluster sampling design was used. The Navy population was divided into clusters based on current duty station ZIP code. A number of these clusters were randomly selected and the demographics of a random sample within this group of clusters were compared to that of a stratified random sample.

Findings

1. Despite the transient, geographically dispersed nature of the Navy, segmenting the Navy population into distinct clusters is feasible. For this study, 199 clusters were created.
2. Overall, the demographics of the cluster and stratified random samples were very similar. On the key demographic variables of location, gender, pay grade, and race, few differences were found between the cluster sample and stratified random sample.
3. The number of commands in the cluster sample was significantly smaller than the number of commands in the stratified random sample.

Implications

1. The results suggest that cluster sampling appears to be a viable option for collecting survey data that is representative of Navy personnel.
2. Since the cluster sample contained fewer commands than the stratified random sample, on-site survey data collection and follow-up efforts may be easier with the cluster sampling approach than with stratified sampling.
3. Results should be viewed as preliminary. Future research should be conducted to statistically compare the results of actual data collected using these techniques in Navy settings.

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Introduction

Background

Navy leadership frequently requires Sailors' attitudes and opinions on various personnel-related issues. This information has typically been assessed through traditional mail surveys (Newell, Rosenfeld, & Culbertson, 1995; Rosenfeld, Newell, & Le, 1998). Over the past ten years, large-scale Navy surveys have suffered a steady decline in response rates (Olmsted & Underhill, 2003; Rosenfeld, Newell, Harris, & Hindelang, 2002). For example, the Navy Equal Opportunity/Sexual Harassment (NEOSH) Survey, which is mailed biennially to a Navy-wide sample, obtained a 60 percent response rate in its first year of administration, 1989. By 1999, the rate fell to 30 percent (Rosenfeld et al., 2002). Decreasing response rates have been a source of concern for Navy leadership, and they have requested practical solutions to address the problem.

While mail survey response rates have steadily declined, the costs associated with these surveys have increased due to rising postage rates and the larger samples and follow-up mailings needed to ensure adequate sample sizes. The problems associated with mail surveys require that alternative data collection techniques be explored. It has been suggested that these difficulties could be addressed by administering surveys at the installation or command level. However, there has been no prior determination in a Navy setting that command-level administration is scientifically sound and results can be reliably generalized to the Navy as a whole. The Navy's transient, geographically dispersed environment adds additional complexity to this type of data collection scheme. This study utilizes the cluster sampling technique to determine if a statistically representative, scientifically valid sample can be developed using randomly selected Navy commands.

Cluster Sampling

Cluster sampling is a probability sampling technique where a defined population is divided into groups or clusters, a number of these clusters are randomly selected, and data are collected from all or some of the observations in the clusters (Fowler, 2002). Sampling within clusters can be classified into three general design categories—single-stage design, two-stage design, and multi-stage design. In one-stage cluster design, all observations in the clusters are selected for data collection, while in a two-stage cluster design, a random sample of individuals within the clusters are included. These two designs differ from a multi-stage cluster design since subjects are randomly chosen from sampling strata defined as one or more characteristics (e.g., gender, race, job position) relevant to a study within the clusters selected for the study. Cluster sampling is the recommended sampling technique when the population of interest is geographically separated and/or data collection will take place on-site (Fowler, 2002; Morgan & Harmon, 1999; Sullivan, Borgida, & Carter, 1988). The advantages of cluster samples are decreased costs, due to sampling in selected areas, and higher response rates in on-site administered surveys.

Since a large percentage of Navy personnel are usually deployed at sea and are therefore inaccessible for on-site data collection, Navy researchers have typically employed mail surveys that utilize simple or stratified random sampling so that they can accurately reflect the entire Navy population. Cluster samples have previously been used in military studies to investigate issues related to youth and veterans' perceptions of the military and military service (Boyle, Brounstein, & Knain, 1983; Bray, Ostrove, Immerson, McCalla, & Guess, 1986). In addition, the Survey of Health Related Behaviors among Military Personnel, a U.S. Department of Defense (DoD) study, uses cluster sampling as a large portion of the study design to determine the prevalence of substance abuse and other health-related behaviors in the military (Bray, Fairbank, & Marsden, 1999). This continuing study has been administered every three years since 1982. Data for this study are collected both on-site at military installations and through the mail for those in remote areas. While the studies described above used the cluster sampling technique, no study to date has systematically compared a cluster sample to a stratified random sample in a military setting.

Purpose

The present study sought to determine the feasibility of using cluster sampling to develop a representative sample of Navy personnel for data collection at randomly selected Navy installations. For this study, the Navy was divided into clusters and the demographics of a cluster sample were compared to that of a stratified random sample.

Method

A comparison of cluster and stratified random sampling was conducted within a larger Chief of Naval Personnel (CNP) Quick Poll study. The CNP Quick Poll was developed to rapidly provide Navy leadership with statistically valid Sailor attitude and opinion data through brief, focused, Web-based surveys. For the poll, one sample of Navy personnel was extracted using the stratified random sampling typically used in large-scale Navy personnel surveys, and another sample was extracted using cluster sampling. The demographics of the two samples were compared to determine the degree of similarity between them. The procedures used to divide the Navy population into clusters, the allocation procedures for the cluster and stratified samples, and the demographic comparisons between the two samples are presented below.

Dividing Navy Population into Clusters

The August 2002 Officer and Enlisted Master Files (OMF/EMF), electronic databases containing personnel information for the Navy, were used to create the final sampling frame and separate Navy personnel into geographic clusters. Demographic information was extracted from these databases for all individuals identified as Active-duty Navy (N = 349,552).

To improve processing speed, a summary or aggregate file was developed by eliminating all identifying information (e.g., name, SSN) and collapsing the person-level data across the following variable categories:

- Current duty station Unit Identification Code (UIC)
- Current duty station ZIP code
- Parent UIC
- Parent ZIP code
- Duty-station location (shore or sea/neutral[1])
- Demographic information (pay grade, race, gender)

This summary file, referred to as *FRAME1* in Figure 1, contained 41,530 records. Next, the summary file was examined for the completeness of the current duty station ZIP code information. Records with valid current duty station ZIP code information were set aside (*FRAME2*) and did not require further examination or cleaning. Records with missing or invalid current duty station ZIP codes were updated using the Parent ZIP code when this information was available (*FRAME3*).

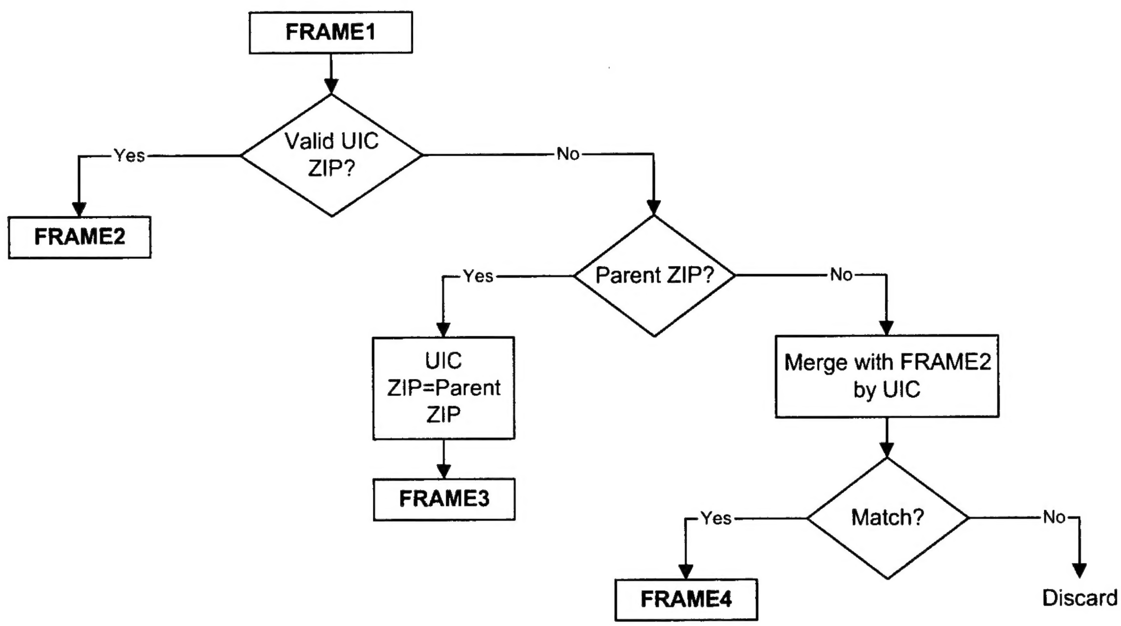

Figure 1: Sampling Frame Construction Procedure.

The remaining records in the summary file were those with both missing current duty station ZIP code and Parent ZIP code information. These records were matched with the *FRAME2* data file by Parent UIC to extract the Parent UIC ZIP code. Matches were not found for 54 records, a total of 371 people. These individuals were assumed to be in mid-

[1] Since neutral duty typically refers to those assigned to an afloat training post, it was combined with the sea duty category.

transfer to another location (e.g., permanent change of duty station) and therefore not currently attached to a command. Since the clusters were to be created with UIC and ZIP code information, these records were discarded.

Finally, the location data of the 41,476 remaining records (*FRAME2*, *FRAME3*, and *FRAME4*) was examined for completeness, as this information was important to the sampling design. Two additional records were discarded from the final sampling frame due to missing location data.

Records in *FRAME2*, *FRAME3*, and *FRAME4* were combined to create the final sampling frame, which contained 41,474 records. These records were sorted by Parent ZIP code, current duty station UIC and current duty station ZIP code, within the two location groups (shore and sea/neutral). Clusters of the Navy population were formed by combining the current duty station UIC and ZIP code records within Parent ZIP code. To minimize variation in the cluster sizes—a factor that affects the efficiency of the survey design and respondent burden—the clusters were formed with no more than 100 current duty station UICs and with at least 250 members of the Navy. Clusters with more than 100 current duty station UICs and ZIP codes were randomly divided into two or more clusters containing at least 250 persons. A total of 199 clusters (88 shore and 111 sea/neutral) were developed using this procedure. Next, the cluster and stratified random sample sizes were calculated using the methods described below.

Determining Cluster and Stratified Random Sample Sizes

The sample sizes were determined using the Sample Planning Tool (Tool). This software uses a Karush-Kuhn-Tucker-based numerical algorithm for computing the sample size and allocation required to satisfy a set of precision constraints. This algorithm computes an allocation that minimizes a specified cost model while meeting or exceeding the required precision constraints (Mason et al., 1995). The Tool is commonly used to determine sample sizes for large-scale DoD and Navy personnel surveys. Table 1 displays the software settings used for the present study.

Table 1.
Sampling Planning Tool Settings for Stratified Random and Cluster Samples

	Stratified Random Design	Cluster Design
Design	Single-Stage Stratified	Stratified Two-Stage Cluster
First-stage Sampling Strata	Location (Shore vs. Other) Rank (Enlisted vs. Officers)	Location (Shore vs. Other)
Second-stage sampling Strata	N/A	Rank (Enlisted vs. Officers)
Data Collection Mode	Navy Messaging System	Navy Messaging System
Number of Contacts	1	1
Study Eligibility Rate	90%	90%
Response Rates by Strata	Enlisted–19% Officers–32%	Enlisted–19% Officers–32%
Cost Model	Same Values Across All Strata	Same Values Across All Strata
Reporting Domains	Enlisted Officers	Enlisted Officers
Prevalence	50% across domains	50% across domains
Precision Constraints	0.05 half-width confidence interval for both domains	0.05 half-width confidence interval for both domains

As displayed in Table 1, the stratified random design used a single-stage design with location and rank (officers vs. enlisted) serving as the strata. In contrast, the cluster design required a two-stage design with location serving as the first-stage strata and rank serving as the second strata.

The Tool uses an iterative process to determine the optimal allocation. The software is allowed to process the data until the results satisfy a minimum cost model and the set of precision constraints within the specified convergence criterion. For both the cluster and stratified random samples, the default convergence criterion (0.0001) was chosen and resulted in the allocation solution displayed in Table 2. As usually occurs, the sample size of the cluster design is larger than the stratified design. The larger sample is used to account for the increased variability within the cluster sample (Cochran, 1963). From the 199 clusters that were created, 11 shore and 10 sea/neutral clusters were determined to be adequate for the cluster sample.

Table 2.
Sample Sizes for Stratified Random and Cluster Samples

Stratification Group	Stratified Random Design	Cluster Design
Shore		11 Clusters
Enlisted	1,126	1,452
Officers	997	1,518
Sea/Neutral		10 Clusters
Enlisted	1,347	1,900
Officers	463	790
Total Personnel	3,933	5,660

The precision and design effects for the stratified random and cluster designs are displayed below in Table 3. For both designs the expected precision is .05. The design effect (DEFF) is the ratio of variance in the chosen sampling design to the variance of a simple random sample (SRS) design. By definition, an SRS design minimizes sampling variance since the selection probability is the same for all sampling units of interest. A design with a DEFF greater than 1.0 is less efficient than an SRS, but may still be appropriate when other important factors (for example, minimized cost) are taken into consideration. The domain-specific design effects for both of the current designs were less than 2.0.

Table 3.
Stratified Random Sample and Cluster Sample
Expected Precision and Design Effect

	Stratified Random Design	Cluster Design
Precision		
Enlisted	.05	.05
Officer	.05	.05
Design Effect		
Enlisted	1.22	1.57
Officer	1.22	1.88

Results

Using the information above, two samples of Navy personnel were extracted from the EMF and OMF databases. As mentioned earlier, for the cluster sample, 11 shore and 10 sea/neutral clusters were randomly selected for the present study; a total of 5,660 individuals were randomly selected from strata within these clusters. For the stratified random sample, 3,933 individuals were randomly selected within the four stratification groups.

The demographics of the stratified random and cluster samples are presented in Table 4. As indicated, few differences were found between the two samples. Both samples contained nearly identical distributions by duty-station location and gender subgroups. Chi-square tests were conducted and showed that significantly more of the lower pay grade enlisted (14.2%) were selected in the stratified random sample than in the cluster sample (11.4%) (X^2 [1, N = 9,595] = 16.58, $p \leq .01$), while a larger percentage of senior officers was found in the cluster sample (18.4%) than in the stratified random sample (15.8%) (X^2 [1, N = 9,595] = 10.95, $p \leq .01$). In terms of race, the stratified sample had a significantly higher percentage of Other (17.6%) than the cluster sample (14.6%) (X^2 [1, N = 9,595] = 15.67, $p \leq .01$). The cluster sample had a significantly higher percentage of Caucasians (70.0%) than the stratified random sample (66.1%) (X^2 [1, N = 9,595] = 16.33, $p \leq .01$).

Table 4.
Demographics of Stratified Random and Cluster Samples

	Stratified Random Sample	**Cluster Samples**
Location Status		
Shore	54.0%	52.5%
Sea/Neutral	46.0%	47.5%
Gender		
Male	85.1%	84.7%
Female	14.9%	15.3%
Pay grade		
E-1 to E-3	14.2%	11.4%[a]
E-4 to E-6	40.8%	40.6%
E-7 to E-9	7.9%	7.2%
W-2 to W-4	1.5%	1.0%
O-1 to O-3	19.8%	21.4%
O-4 to O-6	15.8%	18.4%[a]
Race		
Caucasian	66.1%	70.0%[a]
African-American	16.3%	15.4%
Other	17.6%	14.6%[a]

[a] = significant difference from stratified random sample ($p < .01$).

Discussion

The purpose of the present study was to test the feasibility of using a cluster sampling technique to create representative samples of the Navy population. The demographics of a cluster and stratified random sample were compared and few differences were found between the two. The differences that were found might be expected, since at the command level, the ratio of officers to enlisted, especially senior officers, would be higher due to the command structure and size. However, on the key dimensions of location, gender, pay grade, and race, the demographics of the cluster and stratified random sample were very similar. Thus, the argument can be made that samples drawn from cluster designs can approximate the Navy population at least as well as those drawn using traditional stratified random samples.

One potential drawback of cluster sampling is that the individuals within clusters may be more homogeneous; that is, they may resemble each other more than individuals selected through simple or stratified random samples (Ray, 1983). If a sample is too homogeneous it may not accurately reflect the larger population to which it is being generalized.

The homogeneity issue could not be addressed in the present study since no actual survey data were gathered. A follow-up study should be conducted to determine the degree of homogeneity present in military cluster samples. Given the diverse populations on most military installations (i.e., officers, enlisted, civilians, etc.) this may not be a large threat to the validity of the survey findings. However, it might also depend on the survey topic. For example, surveys dealing with topics where location is important, such as base housing, might show increased homogeneity in the clusters.

While the present study addressed the feasibility of cluster sampling, it suggests an additional practical benefit of cluster sampling for Web-based surveys such as the CNP Quick Poll, where time is of the essence. A cluster sample might decrease the amount of time needed to contact the commands in the sample. If a large number of commands are included in the sample, individually contacting each one (e.g., to gain access to the command, to conduct follow-ups) could become very time consuming. A check of the number of commands in the samples revealed that the stratified random sample contained 1,560 commands while the cluster sample contained 308. Thus, in the proposed Web survey there may be reason to favor cluster samples over stratified random samples. If cluster samples result in fewer commands being selected, it will be easier to establish contact and conduct repeated survey follow-ups with fewer commands than it would be with the many more selected using the stratified sample.

In summary, this study indicates that cluster samples are a viable alternative to stratified random samples, resulting in similar demographics while selecting fewer commands. However, since this study simply compared the demographic percentages of two samples, the results need to be viewed cautiously. Future studies using weighted results from actual operational Navy personnel surveys are required to provide a more rigorous test of the comparability of data collected through these sampling techniques in Navy settings.

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